Test and Training ENabling Architecture (TENA)

TENA BASELINE PROJECT REPORT

Volume VII
Integrated Validation and Verification Plan

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Abstract

There are established guidelines for verifying and validating system properties. [IEEE, 1986] These guidelines propose the following definitions:

- Verification: The process of determining whether or not the products of a given phase of the software development cycle fulfill the requirements established during the previous phase.
- Validation: The process of evaluating software at the end of the software development process to ensure compliance with software requirements.

In layman's terms, verification answers the question: "Did I build the product correctly, according to the specification?" Validation answers the question: "Did I build the correct product, according to its intended use?"

The Test and Training ENabling Architecture (TENA) is a project to develop a common architecture in support of test and training applications. The objectives of this architecture are support of interoperability among facilities, reuse of software, and sharing of information. TENA products include the Technical Reference Architecture (TRA) and the Logical Range Business Process Model (LRBPM). These provide a capability to dynamically assemble resources for individual test or training exercises.

For TENA, verification is a process including review, inspections and tests that will demonstrate conformance of the common architecture and other products to TENA requirements. Validation for TENA will include demonstration that operational systems can be built using TENA products. This process consists of four phases explained in the Integrated Validation & Verification Plan.

Instructions to the Reader

The Test and Training ENabling Architecture (TENA) fiscal year 1997 Baseline Project Report contains 10 volumes and an Executive Summary. This format provides several advantages. For example, you need not read the detailed technical information in the Technical Reference Architecture (Volume IV) unless you wish. We have provided an Executive Summary which should be read by DoD range management executives and others in a decision-making role. It should also be read as a companion volume to technical volumes. The Management Overview contains enough information from the remaining technical volumes to gain a good understanding of the TENA project background, accomplishments to date, and plans for the future. Additionally, Volume IX, Glossary of Terms and Definitions and Volume X, Other Supporting Information, are intended as companion reference volumes for the reader.

Each volume contains an abstract (all are presented in an appendix to the Executive Summary), Table of Contents, Overview, Introduction, and TENA Project Background. The Overview contains information related to the specific volume, identifies the expected readership, and identifies any relationships with other volumes. The TENA Project Background is the same in each volume. Technical volumes are intended to be "stand-alone" documents that will be upgraded as more information becomes available. An acronym and reference listing, (appendices A and B in every volume) is provided, but for detailed definitions and some cited references, the reader should consult Volumes IX and X.

The TENA Project Baseline Report contains the volumes listed below:

Executive Summary
Volume I - Management Overview
Volume II - Product-Line Approach
Volume III - Requirements
Volume IV - Technical Reference Architecture
Volume V - Logical Range Business Process Model
Volume VI - TENA Application Concepts
Volume VII - Integrated Validation and Verification Plan
Volume VIII - Transition Plan
Volume IX - Glossary of Terms and Definitions
Volume X - Other Supporting Information

Table of Contents

List of Figures and Tables

Overview

Purpose

This plan addresses TENA verification and validation throughout the life cycle. It covers the conceptual design, known as the TENA Reference Architecture (TRA), the prototypes, and the installed system capability. These activities are divided into phases as follows:

- Phase I - Verification of Technical Architecture against TENA requirements.
- Phase II - Verification of System Architectures against requirements for range instances. This will be performed through prototypes to test architectural elements.
- Phase III - Validation of implementation against range operator expectations and actual test plans. This will include integration and acceptance testing.
- Phase IV - Installation of the operational system.

The schedule for these phases will span the development and Initial Operational Capability (IOC) testing of systems constructed using TENA products.

Readership

This plan is written for any person interested in the verification and validation of TENA products. It does not contain detailed engineering procedures.

Relationship to Other Volumes

The IV&V[1] plan supports the Product-Line Approach[2] presented in Volume II and the Transition Plan presented in Volume VIII.

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[1] IV&V as a standard term applies to "Independent Verification and Validation." The TENA project has chosen to use the term *integrated* to show the need to integrate across the entire TENA project (Product-Line Approach, Object Model, Logical Range Business Process Model (LRBPM) and the Architecture).

[2] A product-line is a group of products sharing a common, managed set of features that satisfy specific needs of a selected market or mission. [Northrop, 1997] The Product-Line Approach is a methodology for developing and supporting range hardware, software, architectures, and systems in the distributed test and training environment.

TENA PROJECT BACKGROUND

PROJECT NEED

TENA is part of a coordinated response by the Central Test and Evaluation Investment Program (CTEIP) office to several current and emerging challenges in the test and training range and resource community. These challenges include:

- Reducing software development and maintenance cost,
- Utilizing common instrumentation at multiple facilities,
- Responding to the increased demand for multiple-site exercises and/or exercises which cross T&E/training or live/virtual/constructive boundaries,
- Responding to the increased demand for consistency of information between facilities and across phases of the acquisition process, and
- Capturing critical data to support informed customer and management decisions about resource needs, capabilities, and investments.

PROJECT PURPOSE

The purpose of the TENA project is to respond to these challenges through the establishment of an architecture that efficiently and effectively fosters the sharing, reuse, and interoperability between cooperating Department of Defense (DoD) test ranges and facilities, training ranges, laboratories, and other modeling and simulation activities. The expected synergism will permit efficient and effective testing of new and enhanced weapons systems and will vastly improve the scope and fidelity of worldwide joint/combined training.

PROJECT HISTORY

The Test and Training ENabling Architecture (TENA) project concept was formulated in FY95 by a multi-Service working group. This concept was endorsed by the Test and Evaluation Reliance Investment Board (TERIB), the Board of Operating Directors (BoOD), and the Test and Evaluation Resource Council (TERC).

The Navy is the CTEIP Resource Manager for this project, and has established a Joint Project Office (JPO) for the management of project activities at the Naval Undersea Warfare Center (NUWC) Division, Newport, RI.

Shortly after assembly of the Joint Service Team, several critical observations were made:

- The key to interoperability is not connectivity alone, but rather understanding communications content. This is best promoted by defining an open, object-oriented software architecture that could be used by both legacy and newly built systems.

- The process used to plan, schedule, and otherwise coordinate a multiple-facility, multiple-service exercise must be integral to the development of the architecture, or the capabilities it offers might never be fully utilized.

- The architecture must be conducive to refinement over time and coexists with facility-unique applications. This requires a disciplined architecture development/refinement process. The team adapted the Defense Information Systems Agency (DISA) domain-engineering approach to help develop the architecture and recommends the Product-Line Approach for implementation and life-cycle maintenance.

- Significant investments are being made in other closely related areas such as, Defense Modeling and Simulation Office (DMSO), High Level Architecture (HLA) and the Joint Simulation system (JSIMS) program. TENA must leverage as many of these efforts as practical.

- The TENA concept is radically new to our community. Planning for transition is key to its ultimate acceptance.

STATUS

The project team tested its architecture development process in FY96 producing a "Pilot Architecture." This work was reviewed in several public forums. These reviews were highly supportive of TENA's effort. Two consistent suggestions were that TENA should focus first "on breadth, not depth", and that there should be more emphasis on "problem-space vs. solution-space". These considerations and additional engineering effort has resulted in this refined "Baseline Architecture."

The TENA Baseline contains sufficient detail to continue further analysis and risk reduction efforts and is a good vehicle for discussion, experimentation, and refinement. It is not yet appropriate to use these documents as the blueprint for a major system development. After community feedback, results from risk-reduction prototypes, experiments, and other ongoing efforts are synthesized, the cognizant TENA Baseline documents will be updated as "TENA Rev 0." TENA Rev. 0 will be the appropriate source of design information for a TENA-compliant system implementation.

Introduction

This plan provides a review of the goals and foundations for the TENA IV&V process and a discussion of each phase. The process is a tailored version of the DoD recommended approach to V&V. A preliminary schedule is included. Appendix C contains several scenarios that will be used later for validation of certain aspects of the TENA project. The goals of the V&V activity are to:

- *Analyze the architecture for specific attributes.* This will include architecture assessment by creating scenarios for development and use of the architecture with respect to specific characteristics and requirements. The analysis will measure the ability of the architecture to meet these attributes.

- *Verify effectiveness of architecture elements.* This goal will be satisfied by building prototypes which use portions of the architecture to perform realistic system functions.

- *Validate ability of the architecture to support operational systems.* The architecture and components will be used to build actual systems. Validation will be met upon successful acceptance testing of systems.

TENA V&V will be integrated with product development.

TENA V&V PROCESS

DoD DIRECTIVES FOUNDATION

The DoD [VV&A, 1995] has established a Validation, Verification and Accreditation (VV&A) Technical Support Team to develop guidelines for VV&A practices within DoD. We have tailored these guidelines to serve as a basis for VV&A of the TENA development products. The following list provides the generic process for V&V defined by the DoD team and tailored for TENA purposes. These steps will be grouped into specific phases of the TENA process previously mentioned in the overview and as shown in bold text below.

1. *Determine V&V Requirements* **-** This covers determination of the level of effort, techniques, V&V agent, etc. This Integrated V&V Plan will evolve to include all the TENA V&V requirements. **{TENA IV&V Process-Phase I}**
2. *Initiate V&V Planning* **-** V&V tasks should mirror development. They should proceed in parallel with the development and refinement of the TENA architecture, with key development milestones driving the execution of V&V tasks. Task planning will be the first step of V&V for TENA and will collect and review development requirements. It will identify necessary tools and resources. The initial steps provided in this plan are rather general; as the TENA capability evolves, these plans will become more detailed. **{TENA IV&V Process-Phase I}**
3. *V&V the Conceptual Model* **-** For TENA, the conceptual model is the Technical Reference Architecture (TRA) [TENA,1]and its associated Logical Range Business Process Model (LRBPM)[TENA,2]. Verification of the conceptual model only covers analysis and assessment of the TRA.

Step 3 will generally follow the Software Architecture Assessment Method (SAAM) [Clem, 1996] shown below. TENA has already made progress on several SAAM steps and that progress is shown in Italics. The major steps of the SAAM method are **{TENA IV&V Process-Phase I}**:

- ***Gather stakeholders*** **-** The architecture assessment will include input from across the range[3] community. This step identifies categories of stakeholders and makes sure individuals from each category will participate. *The TENA Transition Plan [TENA,3] includes a list of known stakeholders.*

- ***Establish architecture goals*** **-** The stakeholders provide their needs for the system in terms of quality factors such as maintainability, ease of use, and performance, as much as for functional capabilities. *TENA Requirements, Volume III [TENA, 4] provides a baseline set of stakeholder needs.*

- ***Develop scenarios to test for goal compliance*** - The stakeholders express their interactions with the system in terms of scenarios. These may include specific use interactions. *A set of candidate scenarios has been developed by the TENA Project Team and can be found in Appendix C to this volume.*

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[3] Range in this sense means Open Air Range (OAR), but the concept is also applicable to other test and training resources, such as: Hardware-in-the-Loop (HITL) facilities, Installed System Test Facilities (ISTFs), Measurement Facilities (MFs), Integration Laboratories (ILs), and Modeling & Simulation (M&S) systems.

- ***Apply scenarios against the architecture*** **-** The scenarios are exercised by testing their application within the architecture. For example, if a scenario requires the ability to replace one sensor with another during an exercise, ask questions such as: can the architecture support this replacement? If not, how much of the architecture must be changed to accommodate the replacement? *This activity is planned for FY98. Selection of tools to support this analysis is in progress. Initial assessment of Object modeling tools is found in Appendix D.*

- ***Document the scenarios*** **-** Note those that are supported through the architecture, or those that will require architecture changes.

- ***Report results*** **-** Produce an architecture assessment report that describes the architecture, the scenarios, and the results of the scenario- based evaluation.

1. *V&V the design* **-** For TENA, this step will look at a system architecture, built using the elements of the TRA. The goal is to verify the ability of the architecture to define T&E information needs, operations, and connectivity. This step usually focuses on high-risk areas of the design. **{TENA IV&V Process-Phase II}**

2. *V&V the implementation* **-** This step will also look at system architecture once the TRA and at least one TENA application are completely implemented. **{TENA IV&V Process-Phase II}**

3. *V&V the application* **-** This step will be performed at a facility where an actual exercise will use the TENA capability to construct an instance of a logical range[4]. **{TENA IV&V Process-Phase III}**

4. *Perform acceptability testing* **-** For TENA, this step will review the information collected during the overall V&V process to assure usability for constructing a logical range using TENA products. This step will determine if TENA can support real-time operational events on ranges and at facilities. **{TENA IV&V Process-Phase IV}**

TENA DEVELOPMENT APPROACH

A primary goal of the TENA project is to create a capability for assembling a logical range, using the customer's requirements as primary input. With this in mind, the development and V&V approaches must establish the ability of the TENA products to meet this goal.

Figure 1 illustrates the flow of products to and from the TENA architecture process. A set of general TENA requirements forms the basis for architectural decisions: sharing, interoperability, and reuse. In addition, a specific set of features of ranges, including operational requirements, constraints, and mission scenarios, guides the architecture process. From these needs emerged the architecture process, divided into two primary activities: Technical Reference Architecture (TRA) and system architecture. These activities produce the technical reference and system architectures. Following each activity, TENA will conduct a verification activity, to assure compliance of the product with expectations.

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[4] A Logical Range is a set of assets required to conduct a specific test exercise or training event logically assembled into a system used to conduct that exercise or event. Assets may come from one or more facilities.

Figure 2 offers another perspective on the TENA products based on their degree of specificity. The technical reference architecture is very general, containing little system-specific information. It could apply to virtually any system requiring connectivity of remotely distributed systems, data distribution, and distributed execution. For TENA, this meets the interoperability requirement of linking remote resources and range systems. The architecture is also open to the definition of information classes - the types of information that must be shared. Finally, the TRA includes scheduling and execution services to support its reuse across the test and training community.

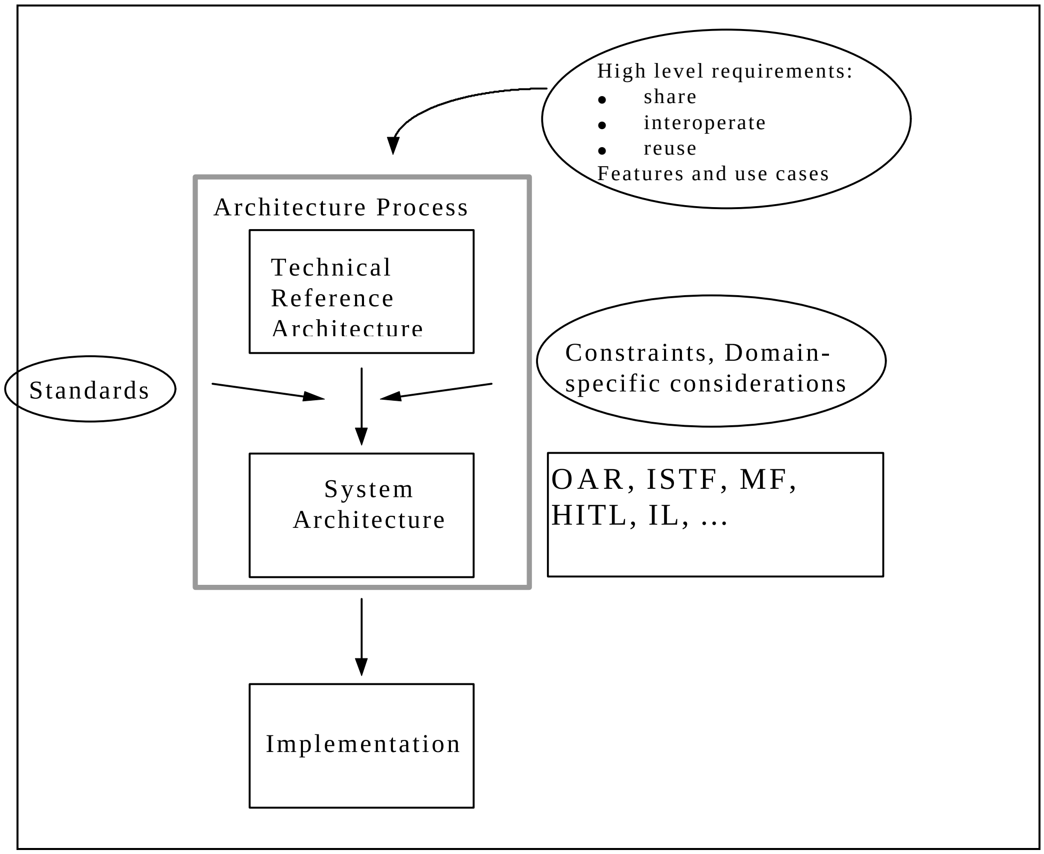

Figure 1. Flow of TENA Products

The system architecture[5] captures domain specific constraints, using the TRA as the basic design structure. For each type of facility, OAR, ISTF, etc., there will be separate system architectures. Application components will be used in the development of the system architecture, incorporating the system information of each type. The implementation[6] of a TENA capability facility for a particular test or training facility must incorporate all of the system information, some of which will come from

[5] The terms *systems architecture, domain architecture*, and *domain specific system architecture* have the same definition throughout the Baseline Report.

[6] *Implementation, instance*, and *range/facility system* share the same definition throughout this Baseline Report.

common application components. The remainder of the implementation will be built from range-specific components, but these components may also share the TRA.

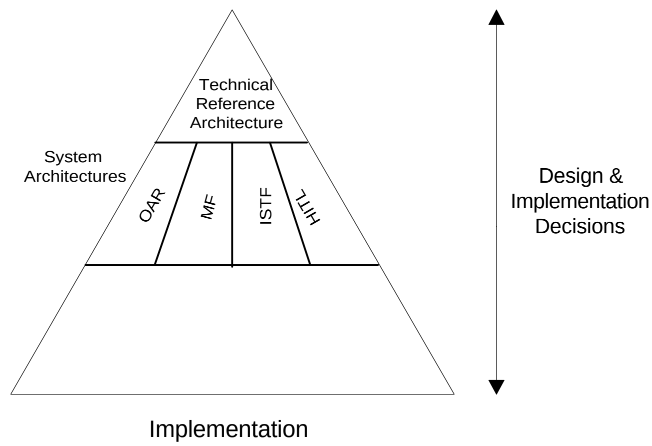

Figure 2. Level of System Information Content in Each of the Architecture Phases

The four phases of the TENA V&V process mentioned in the overview are explained in more detail in the following paragraphs and in Table 1.

Technical Reference Architecture (Phase 1)

The TRA includes the basic services for connecting ranges and facilities, allowing communication between them, scheduling and executing operations, and support for the definition and sharing of information. The TRA defines an infrastructure that shields the applications from the underlying hardware, communications, and interoperation frameworks such as the HLA.

System Architecture (Phase 2)

The system architecture is the framework for constructing systems for particular classes of facilities. While all classes will share the TRA, the OARs, ISTFs, etc., will have specialized needs that will likely require different architectures. Certain types of components may be shared between these architectures, such as those for display; others may be shared within a single class of ranges, such as telemetry.

Implementation (Phase 3)

A range system is built through specialization of a system architecture. Specialization includes:

- Tailoring the system architecture for the specific requirements of that system by integrating range-specific components,

- Defining information classes for information sharing,
- Identifying and scheduling assets at local or remote ranges as required,
- Defining the execution and control for the exercise, and
- Specializing the human-computer interface (HCI) and displays.

Installation (Phase 4)

The fourth and final phase of the TENA V&V process will be to determine whether TENA can fully function in the operational environment at test and training ranges and facilities and that it delivers the promised interoperability, reuse, and sharing.

Table 1 shows the phased process for TENA V&V. The first column, labeled "What" defines the TENA products that will be examined in each phase. "How" explains the methods to be used for Verification/Validation. The third column lists success factors for that phase. The entries in this table will expand as TENA development progresses.

Table 1 also divides the phases into Analysis/Verification and Validation activities. The analysis and verification of TENA includes those activities that concentrate on the architecture as a key TENA product. Phases I and II seek to verify the extent to which the architecture supports desirable architecture system qualities, such as reuse, interoperability, and sharing. Under the validation activity, V&V will establish conformance of TENA products built, using the architecture with range operational expectations.

Table 1 V&V Activities for Each Phase of TENA IV&V

	What	How	Success
Analysis/Verification	Phase I - Technical Reference Architecture (TRA) Product - Architecture Report based on high-level requirements	SAAM method Scenarios for: • Modifiability • Capabilities • Interoperability • Reuse (legacy and new) • Sharing • Business process	TRA supports requirements. Scenarios do not require major redesign.
	Phase II - System Architecture TRA-based architecture for open-air range	Build and test infrastructure. Measure for performance attributes. Use prototypes/experiments as base test cases.	Data sent/received across infrastructure. Buildability from reference architecture. Real-time throughput requirements met.
Validation	Phase III - Implementation	Build and test selected applications integrated with infrastructure. • Ability of TENA "products' to create a logical range. • Ability of logical range to support test and training exercises. • Test template for automatic generation.	Assembled range satisfies software test plan. Perform modifiability experiments from earlier scenarios.
	Phase IV Installation	Conduct parallel testing at the operational level.	Supports interoperability, reuse and sharing.

Schedule and Milestones

The V&V process will be integrated with the overall TENA development plan as shown in Figure 3 which shows a representative schedule.

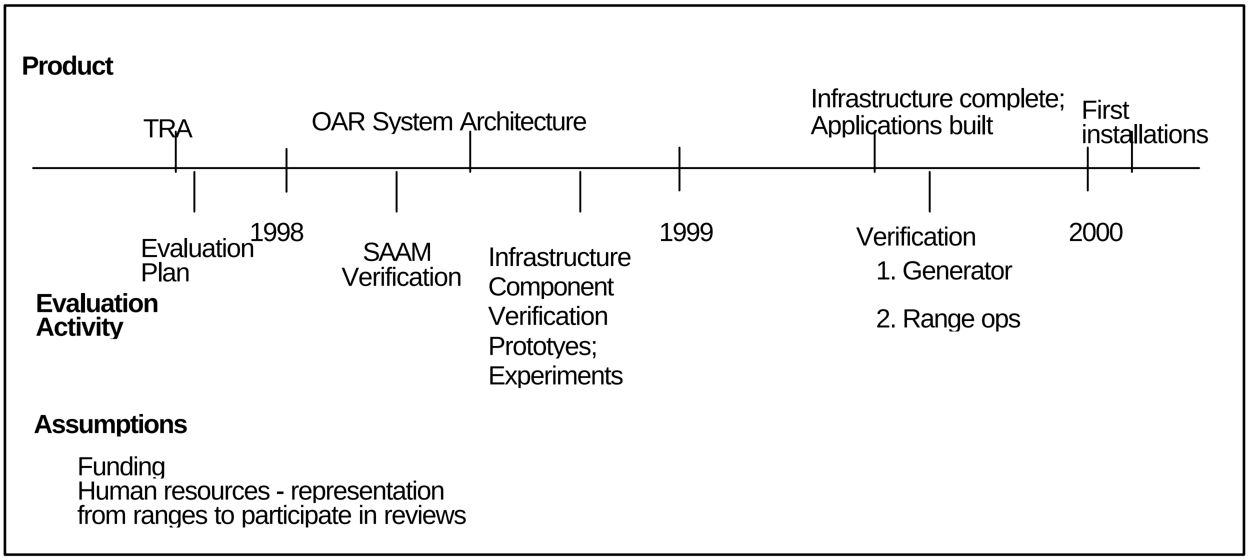

Figure 3. Milestones of V&V Activities

SCENARIOS

Eight candidate scenarios have been developed by the TENA Project Team for use in verification and validation of the Technical Reference Architecture, Logical Range Business Process Model, and other products of the project. These scenarios are designed to encompass a wide range of activities, forces/participants, and missions. Table 2 is a summary matrix of the scenarios found in Appendix C of this volume.

Table 2. TENA Scenario Summary Matrix

Title	**USA VPG**	**JADS**	**JCSAR**	**Roving Sands**	**JTCTS**	**AF/NAVY West Range**	**AAAV**	**SETI**
Number	1	2	3	4	5	6	7	8
Participating Organizations	Natnl Trng Cntr TECOM WSMR RTTC EPG	AF Devlp Test Ctr ADS TCAC	USCENTCOM JCSAR JTF	USCENTCOM FORSCOM USACOM TECOM JITC JIADS JPOC BMDO WSMR EPG	JTF Carrier Battle Group Amphib Ready Group Maritime PrePos Sq Marine Expedn Bgde Marine Air Wing Marine Air Cntgy Force Army Abne Corps AF Composite Wing AF SOF	AF Flight Test Center Edwards Test Range China Lake Test Range Nellis Test Range Point Mugu Test Range Yuma Proving Grounds WSMR CTFs	National Trng Cntr MARCORSYSCOM USMC Air-Grnd TF TECOM Camp Pendleton Point Mugu Test Rng Aberdeen Prvng Grnds Nellis AFB	AUTEC NUWC
Forces/ Participants								
- Navy				✓	✓	✓	✓	√
- Army	✓			✓	✓		✓	
- Air Force		✓		✓	✓	✓	✓	
- Marines				✓	✓		✓	
- Joint		✓	✓	✓	✓	✓	✓	
- Combined				✓				
Mission								
- T&E	✓	✓	✓	✓		✓	✓	✓
- Platform Evaluation		✓		✓		✓	✓	✓
- Situational Awareness	✓		✓	✓				
Training	✓		✓	✓	✓			✓
M&S	✓	✓		✓	✓	✓	✓	✓

SUMMARY

The TENA IV&V plan has presented a process that is tailored from guidelines for VV&A practices within DoD. The process follows plans for TENA development and will ensure that TENA products meet user expectations. The TENA Project team welcomes comments to the basic plan and will upgrade this document as the project progresses.

APPENDIX A - LIST OF ACRONYMS

BoOD	Board of Operating Directors
CTEIP	Central Test and Evaluation Investment Program
DISA	Defense Information Systems Agency
DoD	Department of Defense
DMSO	Defense Modeling and Simulation Office
HCI	Human-computer interface
HLA	High Level Architecture
HITL	Hardware-in-the-loop
IOC	Initial Operational Capability
ISTF	Installed system test facilities
JPO	Joint Project Office
JSMS	Joint Simulation System
LRBPM	Logical Range Business Process Model
OAR	Open Air Ranges
M&S	Modeling and Simulation
NUWC	Naval Undersea Warfare Center
SAAM	Software Architecture Assessment Method
TENA	Test and Training ENabling Architecture
TERC	Test and Evaluation Resource Council
TERIB	Test and Evaluation Reliance Investment Board
TRA	Technical Reference Architecture
V&V	Verification and Validation
VV&A	Verification, Validation and Accreditation

APPENDIX B - REFERENCES

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[TENA, 2] Baseline Project Report, Volume V, Logical Range Business Process Model, 1997.

[TENA, 3] Baseline Project Report, Volume VIII, Transition Plan, 1997.

[TENA, 4] Baseline Project Report, Volume III, Requirements, 1997.

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APPENDIX C - OPERATIONAL SCENARIOS

Appendix D TENA Object Modeling Tool Evaluation Report